Investigating high magnesium soils and the impacts on soybean production. Project # 04-2020

Southern Ag Services, Inc., Dan Prevost, dan@southernaginc.com

Background and Objectives: Magnesium is a critical nutrient for crop development and grain production that is commonly found to be in moderate to high ranges throughout the Mississippi Delta. High soil magnesium exacerbates the already low percentage of available potassium by super-saturating exchange sites with its double positive charge and essentially crowding out the potassium ions. This magnesium induced antagonism is known and generally addressed by increasing potassium rates in fertility recommendations. New knowledge suggests negative effects extending beyond that of simple potassium antagonism. High magnesium can also negatively impact soil structure and related functions. As clay particles disaggregate (i.e., disperse) under high magnesium conditions soil pore space decreases resulting in crusting and compaction thereby reducing soil aeration and water infiltration/internal drainage.

Of 17,204 soil samples collected by Southern Ag in 2019, 60% had base saturation magnesium levels greater than 20%, which may be considered “high. This data served as initial justification for further investigation through this project. The second piece of evidence suggesting a closer look into magnesium is associated with the Mississippi River Alluvial Aquifer (MRVA). Historic analysis of over 2,000 MRVA multi-state water quality samples shows a mean magnesium concentration of 25.8 ppm. Using this concentration, we estimated the amount of magnesium added to be 56.3 lbs/acre/year.

Gypsum is a by-product commonly used to remediate soils by improving soil structure. This is achieved as sulfur contained in the gypsum binds with magnesium freeing up exchange sites which are replaced by calcium. Although gypsum may be a viable option for improving soil properties under high magnesium conditions the effect or potential improvement in soybean yield is unknown. Additionally, several Delta area growers expressed interest in liquid calcium applied via broadcast spray and through irrigation water to improve soil tilth.

OBJECTIVE(S): The intent of this project is to determine the situations and extent that high magnesium is impacting soybean yield and to support location specific management strategies that generate a positive ROI.

1. Determine factors driving situations where soil magnesium negatively impacts soybean yield.
2. Assess irrigation water magnesium levels across different zones of aquifer decline.
3. Evaluate fall applied gypsum in conjunction with deep tillage versus cover crop systems
4. Evaluate liquid calcium applied via irrigation water in cover crop systems.

Report of Progress/Activity

Objective 1 – Assess factors influencing situations where soil magnesium negatively impacts soybean yield.

Activities undertaken for this objective are based on historic soil test and soybean yield data from three farms in the Mississippi Delta located in Sunflower and Leflore Counties. A geodatabase containing spatially referenced soil sample data points representing over 12,000 acres with magnesium base

saturation levels ranging from 10% to 52% has been created. Soil data is from years 2017-2020. Soybean yield data from the same farms was compiled for 2018-2020 crop years. For the initial phase of analysis, yield data points were aggregated and averaged within a 38 ft buffer (combine header width) of each soil sample data point and combined into a master file for analysis with JMP Software (statistics program from SAS). Bivariate analysis of soybean yield versus all typical soil test parameters (pH, CEC, OM, Ca, P, K, Mg, Mn, B, S, Fe, Na, Zn, BS-Ca, BS-Mg, BS-K, BS-H, and BS-Na) was performed and parameters ranked by goodness of fit. BS-Mg (base saturation magnesium) consistently ranked in the top three variables negatively correlated with yield. However, considerable variation in the strength of that relationship by both year and farm were observed. In general, the negative effect and relationship between BS-Mg and yield was stronger in years where average soybean yields were lower. This preliminary analysis supports the general hypothesis that high base saturation magnesium negatively impacts yield.

To investigate the variability behind these relationships, data scientists at Mississippi State University were engaged to subject this data set to multiple machine learning algorithms to determine if a specific combination of soil test parameters combined could consistently predict reduced soybean yield. No clear combinations of soil test parameters consistently correlated with declining yield. Factors that did individually consistently negatively correlate include CEC, magnesium potassium, calcium, and organic matter. It is suspected that external factors (i.e., drainage) not included in analysis are also likely important drivers.

Objective 2 - Assess irrigation water magnesium levels across different zones of aquifer decline.

In year one of the project, groundwater wells were identified near locations of high base saturation magnesium soil and irrigation water samples were collected. Lab analysis indicated a mean magnesium concentration of 31.2 ppm which equates to 70.2 lbs/acre/year magnesium contribution based on conservative irrigation use and efficiency assumptions. Water sampling efforts were expanded in year two to include wells located across different zones of aquifer decline. Spatial analysis of well water data did not indicate any correlation between zone of aquifer decline and magnesium concentrations. The range in well water analysis varied substantially between geographically close wells in multiple incidences. From this observational perspective, it appears that individual well characteristics (e.g. age, depth, etc.) could play a larger role than the estimated aquifer level. Water testing of individual wells where magnesium is a concern is a low-cost option to better understand the situation at the farm level.

Objective 3 - Evaluate fall applied gypsum in conjunction with deep tillage versus cover crop systems

In year one an on-farm trial was conducted in Bolivar County to evaluate soybean yield response to an in-season gypsum application. The field was mapped and zoned using electromagnetic induction technology. Soil samples were collected, composited, and analyzed by zone, the results of which indicate base saturation magnesium ranging from 20% to 38%. Four treatments (0 lbs/ac, 1,000 lbs/ac, 2,000 lbs/ac, and 3,000 lbs/ac) were randomly applied within three block replications. Combine yield data was spatially aggregated from 12 rows for each treatment whereas the spreader ran the middle of the 12 rows from which yield data is reported. No significant differences in yield were observed with ranges from 85.2 to 88.7 bu/ac. Interestingly, the study field did not have the typical yield drag (20-30 bushels) in the high magnesium areas during this production season which is consistent with findings discussed in Objective 1.

Additional gypsum trials were established in the fall of 2021 on two farms with differing farming system strategies. The rationale behind this is that for the sulfur in gypsum to bind with magnesium and leach it out or downward in the soil profile, there must be ample internal water movement in the soil. A cover crop system achieves this over the long-term by creating pore space via roots and increased microbial activity which are stabilized by root exudates and carbon-based substances. This approach is contrasted by mechanical deep tillage which temporarily creates soil pore space which is subsequently lost through consolidation and compaction associated with soil wetting and drying cycles. In both trials, a 1,000 lb/ac rate of gypsum was applied across the field with zero lbs/ac strips left as checks. A 3.7-bushel positive yield response was observed in the cover crop system. The full tillage system resulted in essentially a neutral yield response (+0.3 bu/ac). It is possible the deeper incorporation through tillage could have reduced gypsum activity in the upper soil profile where it had to the most opportunity to provide a positive crop response.

Objective 4 - Evaluate liquid calcium applied via irrigation water in cover crop systems.

On-farm trials evaluating a liquid calcium carboxylate product were established in 2021. Liquid calcium was metered into irrigation water at a rate delivering 1 gallon of product per acre per irrigation event. Three irrigation events were performed in 2021. An electric over hydraulic penetrometer was used to measure soil strength/compaction in 0.25inch increments for the top 24 inches of soil at planting prior to liquid calcium application. These penetrometer measurements were repeated at planting of the 2022 crop. Soil moisture was at field capacity during both assessments. Significant reductions in soil strength/compaction were observed in the top 6 inches, dropping from an average of 495 psi in 2021 to 234 psi in 2022. Physical inspection following the calcium applications in-season reinforced this data as dramatic differences in soil tilth and hardness following the calcium treatment were observed. This treatment alleviated much of the soil “hardness” associated with transitioning to reduced or no-till system.

Impact and Benefits to Mississippi Soybean Producers

High magnesium soils have demonstrated potential to negatively impact soybean yield through antagonism against potassium, degraded soil structure and associated negative impacts. This study provides several key areas of impact and benefit to producers. First, it suggests that both soybean yield loss and remedial options should be viewed in a multi-year context. Yield losses may not occur every year due to climatic factors (i.e., rainfall). Similarly, remedial options such as gypsum should not be evaluated from a single year ROI perspective. Rather, both should be evaluated within the context of soil and production system improvement over time.